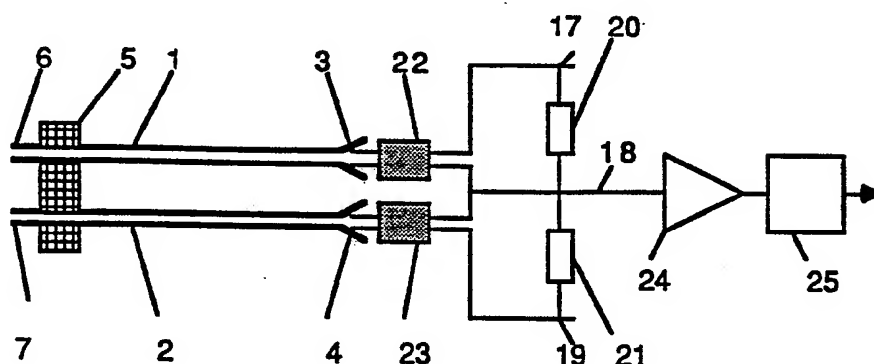




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(54) Title: ACOUSTIC RESPIRATION DETECTOR**(57) Abstract**

The invention is concerned with an acoustic respiration detector consisting of at least two tubular air transmission lines (1, 2, 11, 12) each end of which are connected to microphone elements (22, 23). Close to the other ends of the lines are openings (6, 7), at which turbulence, and hence acoustic signals are created by the incidence of airflow caused by respiration. A holding element (5) secures the openings (6, 7) relative to the mouth or nose of the patient whose respiratory function is to be monitored, and a flow directing element (8), for example formed like a face mask (9) directs the airflow to the openings (6, 7). The microphone elements (22, 23) are connected in a bridge circuit with two voltage supplying leads (17, 19) and at least one signal lead (18). Thereby the sensitivity to mechanical and acoustic disturbances is suppressed.

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Acoustic respiration detector.

In health care, it is often desirable to monitor respiration of a human being (or correspondingly, of an animal in veterinary medicine). For example, respiration is affected during anesthesia, since the respiratory centre of the brain is then brought out of function. Usually, the patient is mechanically ventilated during anesthesia, and is brought back to normal respiration during the wakening procedure. In this state of awakening, there is a risk of apnea (breath arrest), which can be very traumatic and risky to the patient.

Further, it is known that the respiratory function of newborn babies sometimes is not fully developed, which can also lead to apnea, and in some cases to death (the so called sudden infant death syndrome). The direct causes of these tragic cases are still not sufficiently known, but there seems to be a consensus that apnea is the primary symptom, and that this may be easily heaved if it is discovered early enough.

From the cases mentioned above, it should be clear that monitoring respiration is highly important in certain groups of patients. The technological problem of detecting this function has, indeed, been the subject of several innovations and designs. One can classify these detectors into, on the one hand, those which record the respiratory motion of the patient, and on the other, those which detect the flow of air resulting from respiration. The first kind could consist of a belt tied around the chest, with a sensor detecting the variations of length or tension caused by respiration motion. Alternatively, the so called transthoracic impedance is recorded with electrodes placed on the chest wall. Since this impedance is varying when the lungs are filled with air, or emptied, a signal is received which can be used for respiration monitoring.

Common to these methods of recording chest motion is, however, that they are sensitive also to other movements of the patient. This is especially serious, since it can give rise to a false negative response, i.e. the monitoring equipment records an artefact as the desired signal and does not give an alarm despite a possible breath arrest of the patient.

A detector of the flow of expired air does not have this serious limitation, since the detection principle is not coupled to the motion of the patient, given that the detector is fixed to the patient's mouth and nose in such a way that it is hit by the stream of air independently of the motion of the patient, and that the detector is protected from other sources of air flow, e.g. wind or draught.

Gas flow can be detected in several ways. The technical literature is dominated by variants of hot wire anemometry which is based on detection of the temperature change caused by the cooling effect of streaming gas on a heated body. For respiration detection one can make use of the fact that expired air is heated by the human body, making it very simple to place a sensitive temperature sensor in the air flow. This principle has, together with impedance measurements, become the dominant detection principle in clinical practice. It is, however, hampered by several drawbacks. For example, a fast response is required in order to record single breaths. Therefore, only miniaturised temperature sensors, e g thermistors with extremely small mass, can be used. These are difficult to handle, since the very small connecting wires easily break. To guarantee patient safety against electric shocks, the sensor connections must be galvanically isolated from all other equipment, which requires expensive isolation amplifiers. Furthermore, drops of condensed water can develop on the sensor due to the high concentration of water vapour of expired air. Then the response of the sensor is altered, and its function as a respiration detector may be lost.

The invention described in this application solves these and other related problems in a satisfactory manner. The solution consists of acoustic detection of the expired gas. Thereby the general advantages by detecting expired air are fully exploited. Furthermore, the drawbacks, such as sensitivity to condensed water, are eliminated in the acoustic detection principle.

Several other advantages are also obtained. It is possible to physically separate the actual signal receptor function from the area of detection by acoustic signal transmission. The sensor, in this case a microphone, can be placed in a protected location inside an instrument housing.

The acoustic signal transmission takes place in an air transmission line, which simply consists of a length of plastic tubing. By using two, or more, microphone elements connected to one air transmission line each, and connected in a differentially amplifying circuit, it is possible to suppress other acoustic or mechanical signals which could otherwise disturb the desired function. Acoustic signal transmission in air transmission lines is well known. Of course, loss and standing wave phenomena occur in such lines, causing a spectral redistribution of the frequency contents of the signal. This is, however, of minor importance, since a respiration detector could, in general, be based on detection of the prevalence of a certain sound rather than specifying the quality of it.

The present acoustic respiration detector can be divided into one rugged instrument part with a long life, and a receptor part, having a very simple design and a low fabrication cost. The receptor part can then be a disposable item, which is motivated both for hygienic and economic reasons; re-use being more labour intensive. The present invention is explained in more detail in the enclosed claims and figure drawings.

Figure 1 shows the principal outline of the respiration detector according to the invention, whereas figures 2, 3, 4, and 5 show detailed design examples.

From the principal outline in figure 1, the tubular, cylindrical air transmission lines 1 and 2 are seen, connected in the ends 3 and 4 to microphone elements 22, 23. The microphone elements can, for example, be electret elements, i.e. condenser microphones with built-in polarisation and preamplifier. Miniature electret elements are commercially available from several manufacturers. The connection between the elements 22, 23 and the line ends 3, 4 should be leak-proof so that acoustic signals from the ambient are not picked up by the microphone element. The air transmission lines 1 and 2 can have a length of 50 - 300 cm and consist of flexible tubing of poly vinyl chloride, poly ethylene, or the equivalent, with an inner diameter of 1 - 3 mm, and an outer diameter of 2 - 6 mm. The other ends 6, 7 of the lines 1, 2 are open and should be positioned in the flow of air caused by respiration. Fixation of the ends 6 and 7 is made with a holding element 5, which could, in the simplest case be a piece of adhesive tape but which could also have a more complex design and function. For example, the holding function can be performed by rubber bands tied around the patient's head. The openings 6, 7 of the lines 1, 2 do not need to be located at the end surface of the line but could be located along the mantle surface of the line. Furthermore, it must be pointed out that the openings 6, 7 only need to be open in acoustic sense. It could, for example, be an advantage to provide these with a porous filter, a thin, flexible membrane, or the like, to prevent foreign particles and condensed water from blocking the acoustic signal transmission.

The microphone elements 22, 23 are connected in a bridge circuit with voltage supplying leads 17, 19 and a common signal transmitting lead 18. An amplifier 24 and a band pass filter are connected to give the signal the required amplitude and noise immunity. In the bridge circuit, resistive or capacitive impedances 20, 21 can be incorporated to compensate for individual variations in sensitivity of the microphone elements 22, 23. In practice, this is done in such a way that the microphone elements are subjected to one and the same sound source, and the magnitude of the impedances 20, 21 are adjusted until the detector is sensitive to the momentary pressure difference between the microphone elements 22, 23, whereas the sensitivity to common acoustic noise is practically none at all.

A gas flow at the line ends 6, 7 gives rise to turbulence, and noise-like acoustic signals in the respective line ends 6, 7 which are not correlated to each other. These uncorrelated signals will add according to $S = (S_1 + S_2)^{1/2}$, where S_1 and S_2 are the signals in the respective line ends, and S the resulting signal, according to known signal theory, and therefore give rise to a net output signal from the signal lead 18 of the bridge circuit.

Figure 2 shows a detailed picture of a design of the open ends of the air transmission lines 1, 2. Besides the holding element 5 there is also a flow directing element 8, designed to direct the stream of air caused by respiration towards the line ends 6, 7. Besides the flow directing

function, this element may also concentrate the air flow by restricting it through a more narrow area. The flow directing element 8 can be designed in many possible ways. It is, for example, possible to use acoustic resonance phenomena by adapting its inner volume and its opening area. Such resonators, called Helmholtz cavities, are well known in many musical instruments. Other types of resonators can also be built into the flow directing element, for example vibrating reeds, and other mechanical elements. The use of resonance phenomena has the advantage that the bandwidth of the signal is more limited, which makes it possible to choose a more narrow band passfilter 25. This in turn leads to further improved suppression of noise and disturbances.

The flow directing element 8 with or without an acoustic resonator function can have the form of a face mask 9 as shown in Figure 3. The face mask 9 covers both the mouth and the nose of the patient. Inspired and expired air passes through an opening 10, the area of which can be chosen so that a concentration of the air stream is obtained during passage through this opening 10. The flow directing element 8 can advantageously be fabricated as a moulded plate of polymer, textile or cellulose-based material.

In figure 4 a special design of the air transmission lines 11, 12 built in a common polymer mantle 13, e g poly vinyl chloride or poly ethylene, is shown. Each of the lines 11, 12 are connected in the same way as shown in Fig 1 to a microphone element. The common mantle, or a corresponding mechanical coupling between the lines 11, 12 give the advantage of less sensitivity to mechanical disturbances in the form of movements of the lines. Since such movements in this case leads to identical noise signals in the lines 11, 12 there will be no net signal from the bridge circuit.

Figure 5 shows a connector which can be incorporated into the air transmission lines 1, 2, 11, 12. The connector consists of two dismountable units 14 and 15, which by connection can be locked by threads 16. Alternative solutions, e g a bayonette lock, are, of course conceivable. Introducing connectors into the system means that the receptor part, eventually a disposable item, can be separated from the instrument part.

The acoustic respiration detector as defined by the enclosed claims can be given a highly variable detailed design using known technology.

Claims.

1. Detector of air flow at the respiratory organs of a human being or an animal characterised in at least two tubular air transmission lines (1, 2, 11, 12) at one end of each (3, 4) there is at least one microphone element (22, 23) and that close to the other ends there are openings (6, 7), and that there is at least one holding element (5) by which said air transmission lines (1, 2, 11, 12) are secured so that said openings (6, 7) are exposed to said air flow.
2. Detector according to claim 1 characterised in at least one flow directing element (8) for directing and/or concentrating said air flow to the openings (6, 7) of said air transmission lines (1, 2, 11, 12).
3. Detector according to claim 1 characterised in that said flow directing element (8) is formed as a face mask (9) covering the mouth and nose of said human being or animal, and that said air flow is passing through the openings (6, 7) of said air transmission lines (1, 2, 11, 12), eventually through an opening (10) in said face mask (9).
4. Detector according to claim 1 and 2 characterised in that said flow directing element (8) or part thereof has an acoustic resonator function.
5. Detector according to claim 1 characterised in that said air transmission lines (1, 2, 11, 12) consist of one tubular line (13) having at least two air channels (11, 12).
6. Detector according to claim 1 characterised in at least one connector (14, 15) for connecting and disconnecting said air transmission lines (1, 2, 11, 12) to said microphone elements (22, 23).
7. Detector according to claim 1 and 6 characterised in that said connector (14, 15) can be locked in connected or disconnected state by a lock (16) of thread- or bayonette type.
8. Detector according to claim 1 characterised in that said microphone elements (22, 23) are connected in a bridge circuit (17, 18, 19) with at least two leads (17, 19) for voltage supply and at least one signal carrying lead (18).
9. Detector according to claim 1 and 8 characterised in that resistive or capacitive impedance elements (20, 21) are part of said bridge circuit (17, 18, 19).
10. Detector according to claim 1 characterised in that at least one amplifier (24), and at least one band pass filter (25) are connected to the signal lead (18) of said microphone elements (22, 23).

AMENDED CLAIMS

[received by the International Bureau
on 1 July 1991 (01.07.91);
original claims 1,5 and 6 replaced by new claim 1; remaining claims
renumbered as 2-8; new claim 9 added (1 page)]

1. Detector of air flow at the respiratory organs of a human being or an animal, characterised in
at least two tubular air transmission lines (1, 2, 11, 12) positioned alongside, having a common
mantle (13), or being otherwise mechanically coupled,
at least one microphone element (22, 23) that can be connected or disconnected to the ends (3, 4)
of each of said air transmission lines (1, 2, 11, 12) by means of connectors (14, 15),
openings (6, 7) in the vicinity of the opposite ends of said air transmission lines (1, 2, 11, 12)
at least one holding element (5) by which said air transmission lines (1, 2, 11, 12) are secured in
such a way that said openings (6, 7) are exposed to said air flow.
2. Detector according to claim 1 characterised in at least one flow directing element (8) for directing
and/or concentrating said air flow to the openings (6, 7) of said air transmission lines (1, 2, 11,
12).
3. Detector according to claim 1 characterised in that said flow directing element (8) is formed as a
face mask (9) covering the mouth and nose of said human being or animal, and that said air flow is
directed to the openings (6,7) of said transmission lines (1, 2, 11, 12) by passing through openings
(10) in said face mask (9).
4. Detector according to claim 1 and 2 characterised in that said flow directing element (8) or part
thereof has an acoustic resonator function.
5. Detector according to claim 1 characterised in that said connector (14, 15) can be locked in
connected or disconnected state by a lock (16) of thread or bayonette type.
6. Detector according to claim 1 characterised in that said microphone elements (22, 23) are
connected in a bridge circuit (17, 18, 19) with at least two leads (17, 19) for voltage supply and at
least one signal carrying lead (18).
7. Detector according to claim 1 and 8 characterised in that resistive or capacitive impedance
elements are part of said bridge circuit (17, 18, 19).
8. Detector according to claim 1 characterised in that at least one amplifier (24) and at least one band
pass filter (25) are connected to the signal lead (18) of said microphone elements (22, 23).
9. Detector according to claim 1 characterised in that said air transmission lines (1, 2, 11, 12) are
secured by the holding element (5) in such a way that said openings are exposed to air flow from
both the nostrils and the mouth of said human being or animal.

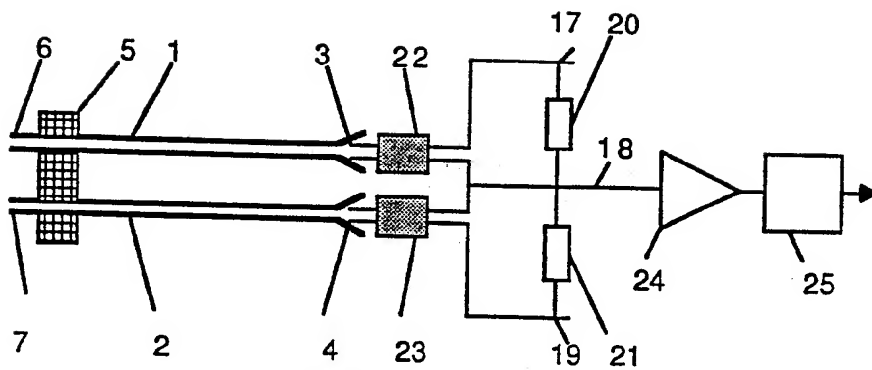


Fig 1

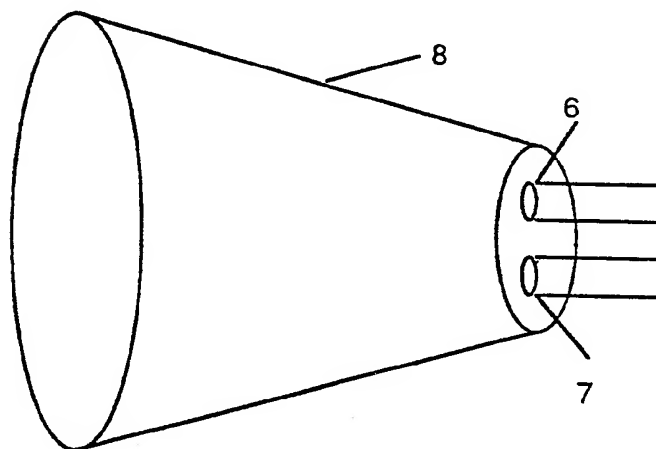


Fig 2

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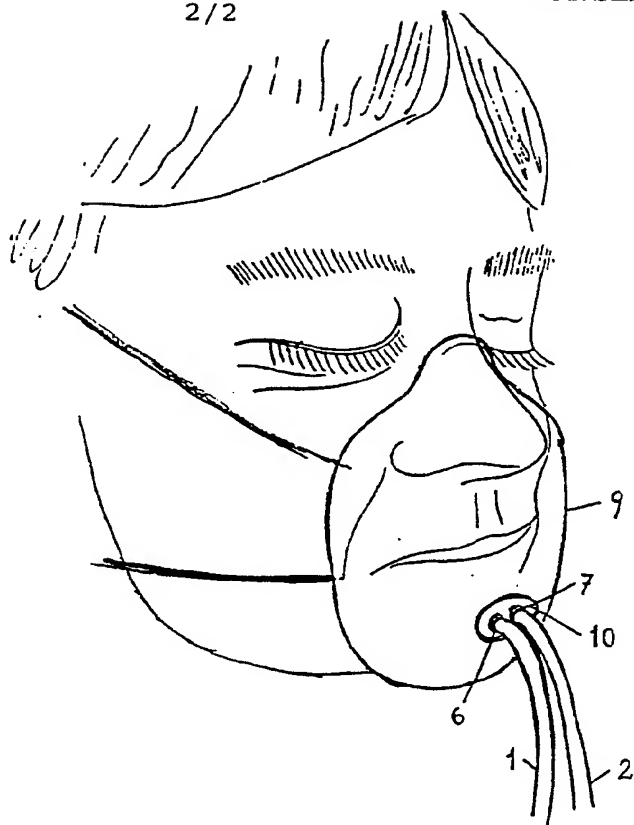


Fig 3

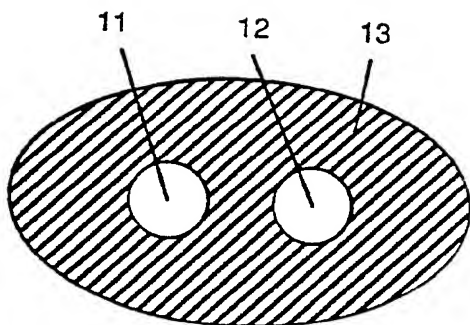


Fig 4

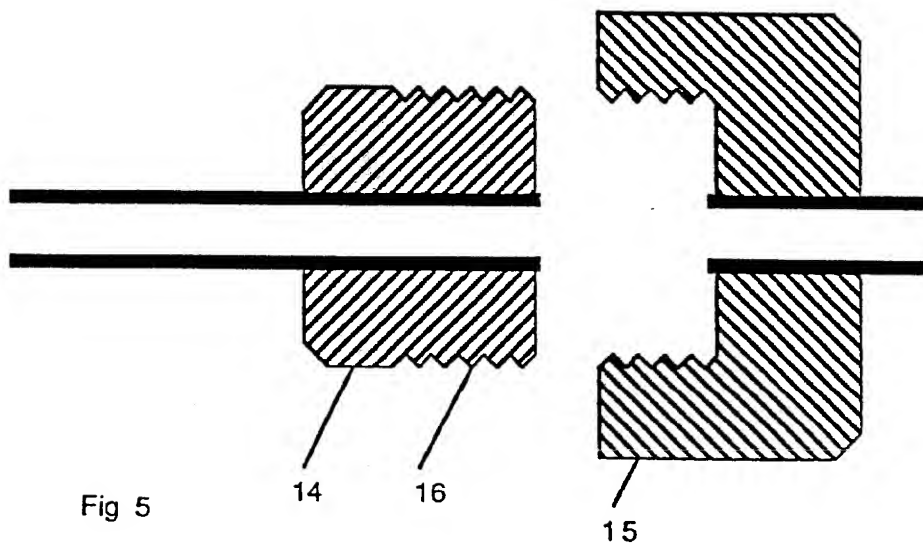
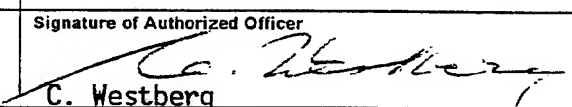


Fig 5

SUBSTITUTE SHEET

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 91/00099

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC IPC5: A 62 B 18/08		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC5	A 62 B; A 61 M	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched ⁸		
SE,DK,FI,NO classes as above		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
Y	US, A, 4475559 (HORN) 9 October 1984, see column 3, line 44 - line 55; figure 5; claim 1 --	1
Y	US, A, 4438772 (SLAVIN) 27 March 1984, see figure 1; claim 1 --	1
Y	US, A, 4602644 (DIBENDETTO ET AL) 29 July 1986, see column 2, line 37 - line 55; column 7, line 22 - line 42; figures 1-3,7 --	2-10
A	DE, A1, 3707952 (HÖRMANN, ERNST) 22 September 1988, see the whole document -- -----	2,3
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>* Special categories of cited documents:¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search		Date of Mailing of this International Search Report
6th May 1991		1991 -05- 1 5
International Searching Authority		Signature of Authorized Officer
SWEDISH PATENT OFFICE		 C. Westberg

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.PCT/SE 91/00099

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4475559	84-10-09	NONE	
US-A- 4438772	84-03-27	NONE	
US-A- 4602644	86-07-29	NONE	
DE-A1- 3707952	88-09-22	NONE	